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AUTHOR	Scholten, Ingrid
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ABSTRACT

This paper describes the effect of supplementary multimedia instruction on the pattern of growth of student learning of normal swallowing. On four occasions, up to 190 speech pathology students from four Australian universities completed a free-response task designed to assess students' learning of core information. Scripts were scored using a valid and reliable key. Hierarchical linear modeling was used to measure change in students' understanding over time. Within-student predictor variables included time, whether or not the student had used specific instructional technology, and details of clinical practica; between-student variables included site, grade point average, age, and gender. Students did improve following instruction and multimedia enhanced performance, with increased duration of use resulting in higher scores. Other influential variables were also determined, including site, gender, and aptitude. The discussion of the findings addresses the implications for teaching. (Contains 33 references.) (Author/MES)

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THE INFLUENCE OF SUPPLEMENTARY MULTIMEDIA INSTRUCTION ON STUDENTS' KNOWLEDGE OF NORMAL SWALLOWING: AN AUTHENTIC INVESTIGATION OVER TIME

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Ingrid Scholten
Dept. of Speech Pathology, School of Medicine
Flinders University of South Australia, Australia
ingrid.scholten@flinders.edu.au

Abstract

This paper describes the effect of supplementary multimedia instruction on the pattern of growth of student learning of normal swallowing. On four occasions up to 190 speech pathology students from four Australian universities completed a free-response task designed to assess students' learning of core information. Scripts were scored using a valid and reliable key. Hierarchical linear modelling was used to measure change in students' understanding over time. Within-student predictor variables included time, whether or not the student had used specific instructional technology and details of clinical practica, and between-student variables included site, grade point average, age, and gender. Students did improve following instruction and multimedia enhanced performance, with increased duration of use resulting in higher scores. Other influential variables were also determined, including site, gender and aptitude. The discussion of the findings addresses the implications for teaching.

Keywords

dysphagia, hierarchical linear modeling, information technology, student learning

Purpose

Over the past several decades there have been increasing expectations that information technology (IT) would "revolutionise higher education" (DEETYA, 1998, p. 59) and not only improve access but also enhance learning outcomes and reduce the costs of teaching, research and administration (Alexander, 1999). However, it is difficult to answer questions about the effectiveness of IT and results have been controversial. Indeed, the discussion is often impassioned (see, for example, Tripp, 1996; Reeves, 1996). Information technology is motivating (Atkins, 1993; Gunn, 1999) and time-efficient (Atkins, 1993; Oliver, 1998). There are many claims that IT enhances learning outcomes (Green & Gilbert, 1995; Tripp, 1996), and different media have been shown to affect learning in different ways (Furnham, Gunter & Green, 1988; Salomon, 1984). However, several studies have shown a lack of significant differences in learning outcomes when using IT (Clark & Craig, 1992; Clark & Solomon, 1986). It would appear that information technology can either help, confuse or confront students (Linn, 1992).

In spite of the difficulties with this body of research, there appears to be a range of learning activities that lend themselves well to IT, particularly when used to support the learning of conceptually difficult topics (Atkins, 1993; Clark, 1984). The swallowing process is a complex integrated sequence, largely hidden from view. An interactive multimedia program, *The Dynamic Swallow*; (Scholten & Russell, 2000a) was specifically designed to strengthen the student's core experience (Graves, 1989; Graves, Henshaw, Oberlin, & Parker, 1997) when learning about dysphagia (swallowing disorders).

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Speech pathology students had been noted to have difficulty with fundamental issues related to normal swallowing. They appeared not to be well motivated to learn about normal functioning, and this inadequate preparation resulted in a lack of understanding of the complex issues around diagnosis and treatment. Interactive multimedia was chosen to address these limitations because of the ability to use multiple representations – text, graphics, animations, video and voiceover, to teach a hidden anatomic and physiological process. The selected learning design is interactive and uses simple simulations, in which users can deactivate certain aspects of the swallow and observe the effects of impairment, exploiting students' interest in disorder to help them learn about normal function. In addition, the program incorporates authentic diagnostic radiographic images, exposing users to aspects of professional practice at an early stage of their learning.

It is known that context is important to all learning, including that involving IT. Any evaluation of the influence of IT must account for the effects of individual differences among students with respect to factors such as aptitude, knowledge, skills, attitudes, previous experience and motivation (Reeves, 1992). The challenge is to employ sound strategies for assessing the impact of technology that are sensitive to the myriad features of interest (Gunn, 1999; Oliver, 1998; Reeves, 1992). The study design and analytic methods used in the present study ensure that such differences were largely accounted for. Authentic evaluations review the situation as a whole, rather than the effect of the resource alone (Oliver, 1998). The present study evaluates the contribution of this specific multimedia program to students' learning of the normal swallowing process in an authentic setting in which the CD-ROM was available for use as a supplementary learning resource.

Determining the effectiveness of educational innovation depends on accurate measurement of individual learning and investigation of the relationship between changes in learning and the educational practices. The correlates of growth are studied "to detect inter-individual differences in the growth parameters that are systematically related to some selected background characteristics of interest" (Willett, 1989, p. 413).

This paper extends earlier work that determined speech pathology students' knowledge of the normal swallowing process, concepts that are central to developing an adequate knowledge of dysphagia (Scholten, 2000; Scholten, Keeves & Lawson, *in press*). The paper reports on the growth in students' knowledge across four occasions that span the 15-week period of formal academic learning and into the following semester. It assesses the influence on such learning of factors associated with both the student and the instructional environment, with an emphasis on the use of multimedia enjoyed by students and determined by experts and teachers alike to be likely to contribute positively to learning (Scholten & Russell, 2000b). It is not only important to be able to describe the pattern of change but also to be able to provide reasons for any differences.

Method

One hundred and ninety undergraduate speech pathology students (183 females and 7 males) from four Australian universities participated in the study. On four occasions, 0) before commencement of lectures in the relevant topic (although after a topic covering basic anatomy and physiology); 1) immediately after the lecture(s) on normal swallowing; 2) on completion of the topic in which the relevant material was covered; and 3) two months later, students were asked to respond to the prompt: "*Describe the swallowing process in as much detail as possible*", a task that was completed in approximately ten minutes. Demographic information was also collected to enable multilevel analysis to be undertaken in an effort to learn about the influence of background characteristics. The within-student level predictor variables of interest included testing occasion (TIMEs 0, 1, 2 & 3), use of the program, *The Dynamic Swallow* (Scholten & Russell, 2000a), and observation of relevant clinical experiences (PRAC). The variables at the between-student level included university attended (SITEs 1, 2, 3 & 4), grade point average (GPA: 4.00-4.99; 5.00-5.99 and 6.00-6.99), AGE (under 25 or 25 and over) and GENDER. The scripts were collected by the respective teachers and returned to the investigator.

Scoring of Responses

Response scripts were collated and combined. Scripts were scored randomly by the investigator using a scoring key. Inter and intra-rater reliability had been established as above 0.87 (Scholten, Keeves & Lawson, *in press*). The quality of students' knowledge, as revealed in their written scripts, was assessed using the SOLO Taxonomy (Biggs & Collis, 1982). The scoring rubric evaluated 10 key features of swallowing, each of which received a score of 0, 1, 2 or 3, depending on the quality of the response (Scholten, Keeves & Lawson, *in press*). The partial credit model of Rasch analysis (Andrich, 1997) was employed to determine a hierarchy of feature difficulty and scale the scores. Scaled scores were normally distributed (mean = -1.47, standard deviation = 1.31; minimum = -5.45 and maximum = 1.92; kurtosis = -0.25 and skewness = -0.35).

Analysis

While a range of conventional analytical techniques such as ANOVA or MANOVA were available for the present analysis, they are not able to take into account the clustering of cases within groups (students at particular sites, generally known as the 'unit of analysis' problem). These techniques result in misleading estimates of significance and to false conclusions when applied to problems involving multilevel data structures (Goldstein, 1999, pp. 2-9).

The questions that arise in this study were answered with Hierarchical Linear Modelling (HLM) (Bryk & Raudenbush, 1992). Hierarchical Linear Modelling is able to describe the pattern of within-student change and the effects on that of between-student characteristics. Additionally, HLM can consider the interactive effects across these levels, overcoming the problems associated with conflation of individual and group effects. In this study changes over time in students' performance (within-student variation) and the influences of student characteristics (between-student variation) on performance formed two levels within the system being investigated. Students' Rasch scaled score on the test of knowledge of the normal swallowing process was the dependent variable.

Results

Data were available for a total of 190 third year students, but there was a considerable withdrawal from the study over time. Prior to the topic commencement 181 students took part, dropping to 160 participants immediately after instruction, with only 82 students remaining for the third and fourth occasions. Only 41 students completed the test on all four occasions. This dropout rate demands some explanation, as there may be systematic bias in the sample.

All available Australian speech pathology programs with a dysphagia topic agreed to participate in the study. (Two sites were excluded from final analysis). Consequently the sample is very representative of the target population. Over 80% of potential students agreed to participate initially, although it is acknowledged that there remains a level of self selection, as ethical requirements of research with human subjects does not permit compulsory participation. Even if one did coerce participation, there is no guarantee that such students' efforts would be indicative of their abilities. Although it is possible that weaker and less motivated students dropped out of the study, there is no reason to believe that this would have influenced the results generally.

Students' scores on each of the 10 key features of swallowing were summed to give a total out of 25 points. Figure 1 presents the overall mean response scores for each testing occasion (5.69 +/- 2.29; 10.16 +/- 3.04; 11.51 +/- 3.85; 10.61 +/- 3.29).

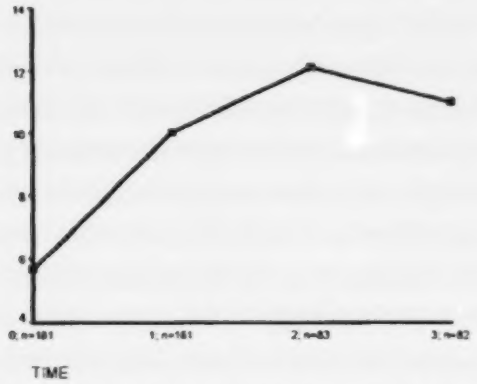

Figure 1: Overall mean response scores associated with each data collection point (TIME)

HLM Analysis

Students with two or more data points were included in the analysis. The data pool was further reduced to 151 cases because of difficulties with the administration of the test instrument at one site that resulted in some missing demographic data. However, the estimation procedures employed take into consideration the reliability of the data with respect to the number of time points involved. Hence, although the data pool is reduced from the total data available, the results obtained can be interpreted with confidence.

The analysis provides a reliable estimation of only three parameters for the effects of predictors at Level 1 because there are only four testing occasions, restricting the investigation to some degree. Consequently, a prudent approach was required in considering those variables which might offer the most sound explanation for change in student performance. Dummy dichotomous variables were constructed for SITE and TIME to facilitate examination of their influence on student learning. Because the effect over time was not linear (with testing occasions spaced differentially at the participants' institutions, depending on the structure of the topic and when the instruction took place) several additional dummy variables were created. These proxies for time were: INTER, which separated the first occasion from the others, reflecting the fact that at and after TIME 1 students had been exposed to intervention; DELAY, which separated TIMEs 0 and 1 from TIMEs 2 and 3, to capture the fact that some time had passed since the relevant lectures on normal swallowing; and INTOPIC, which separated TIMEs 0, 1 and 2 from TIME 3, to reflect the fact that the final testing occurred two months after the completion of the topic.

In the first step of analysis a sufficient statistics matrix was created (Bryk, Raudenbush & Congdon, 1996). The descriptive statistics generated in this way are presented in Table 1. The maximum number of iterations for the final analysis was set at 5000, but considerably fewer iterations were required for the successive steps involved in the analysis of the data.

Evolution of Models

The fully unconditional (null) model was calculated initially in order to partition variance into within and between-group components (see Table 4). This determines the variance explained as predictors are added to the model to reduce both the unexplained variance and the deviance. No predictors are included in the null model and any Level-1 or Level-2 effects are a consequence of only the error terms. The intra-class correlation was low (0.08), indicating that the variance between students was small in comparison with the within-student variance. That is, students were more like other students in their performance at any one time than when comparing their own performance over time. This is consistent with the notion that students' performance changed dramatically as they learned the material in question.

Level-1 Descriptive statistics N = 394					
	Code	**Mean**	**SD**	**Min.**	**Max.**
TIME	0, 1, 2, 3	1.09	1.05	0	3
CD	0, 1, 2, 3	0.44	0.84	0	3
PRAC	0, 1, 2	0.25	0.55	0	1
SCALED SCORE		-1.49	1.37	-5.45	1.92
INTER	0 1 1 1	0.64	0.48	0	1
INTOPIC	1 1 1 0	0.85	0.36	0	1
DELAY	0 0 1 1	0.30	0.46	0	1
Level-2 Descriptive statistics N = 151					
SITE 1	1 0 0 0	0.43	0.50	0	1
SITE 2	0 1 0 0	0.06	0.24	0	1
SITE 3	0 0 1 0	0.32	0.47	0	1
SITE 4	0 0 0 1	0.19	0.40	0	1
GPA		4.97	0.66	3.00	6.40
AGE		22	5.09	19	48
GENDER	0, 1	0.04	0.20	0	1

Table 1: Descriptive statistics for HLM analyses

The final model (or models) is arrived at successively by inserting variables of interest into the equations for both Levels 1 and 2 and conducting exploratory analyses to determine whether additional variables might enhance the model. The explanatory power of a model can be ascertained by calculating the variance explained and comparing this with that explained in the null model and by examining the change in deviance. The evolution of models in this study is summarised in Table 4, which depicts the variables included at Levels 1 and 2 for each model and provides values for sigma squared and the deviance which both help to evaluate the explanatory power of the model. The most powerful model is that with the lowest deviance. Because the design limitations of the study would not permit all variables of interest to be modelled simultaneously models related to key variables were calculated separately. That pertaining to use of IT is reported here.

Final Model: The Influence of Multimedia-based Supplementary Instruction

Because the effect of using the instructional CD-ROM, *The Dynamic Swallow* (Scholten & Russell, 2000a) was of particular interest this variable was modelled after key variables related to the effect of intervention and time had been explored. The variable INTER (intervention) was retained since it was shown to exert a strong influence on students' performance. In order to investigate the influence of IT, the variable CD was included at Level 1. Exploratory analysis had suggested that potential Level 2 predictors might include SITE 4, GENDER and GPA, which were included in this model.

Level-1 Model

$$Y = B0 + B1 * (INTER) + B2 * (CD) + R$$

Level-2 Model

$$B0 = G00 + G01 * (SITE\ 4) + G02 * (GENDER) + G03 * (GPA) + U0$$
$$B1 = G10 + U1$$
$$B2 = G20 + U2$$

Table 2 demonstrates that the inclusion of CD resulted in a somewhat better model than the majority of earlier ones (see Table 4). Variance explained at Level 1 has risen from 43 per cent in Model 1 to 68 per cent in the final model.

This model, summarised in Table 3, indicates that students' starting point, the intercept, is influenced by both their GPA and GENDER, with students having better academic records doing better than their peers and, interestingly, with male students outperforming the females when other

factors are controlled. In addition, students from SITE 4 had an initial advantage compared with students from other sites. There is a strong effect (1.67) for intervention (INTER), with students benefiting significantly from instruction about the normal swallowing process. A smaller, but equally significant effect for CD use (0.22) is also observed. Students who use supplementary multimedia improve their scores. Critically, the more time that is spent with this form of learning, the better is students' performance, increasing by 0.22 units for each level of CD use (0, 1, 2 and 3), with no saturation effect detected. Exploratory analysis suggested that all students who used the CD improved, regardless of their opportunity for clinical observation, site, GPA, age, or gender.

This model could not be further specified and tested because only four time points were included in the data set.

Fixed Effect		Coefficient	Standard Error	t -ratio	*p* -value
For INTERCEPT1, B0					
INTERCEPT2	G00	-4.36	0.52	-8.41	0.00
SITE 4	G01	0.52	0.15	3.50	0.00
GENDER	G02	0.55	0.14	3.90	0.00
GPA	G03	0.31	0.10	3.14	0.00
For INTER slope, B1					
INTERCEPT2	G10	1.67	0.09	18.19	0.00
For CD slope, B2					
INTERCEPT2	G20	0.22	0.06	3.43	0.00

Table 2: Fixed effects for the HLM Final Model

	Within-student Predictors	Between-student Significant Predictors
"Final" Model	INTER, CD	B0 = SITE 4; GPA, GENDER
	There was an overwhelming effect of instruction (INTER) for all students. The effect of using the CD was also positive, suggesting that students who used instructional multimedia in self-directed learning improved their scores, with a stronger effect with increased duration of use. The final model indicated that students' starting point was influenced by both their GPA and GENDER and that students from SITE 4 had an initial advantage.	

Table 3: Summary of Final Model

Model	Level 1 Variables of interest	Level 2 Variables of interest	df	Sigma Squared	Deviance
Null			150	1.72	1364.62
1	TIME		150	0.99	1214.24
2	INTER, INTOPIC		150	0.58	1104.77
2A	INTER, DELAY		150	0.44	1094.51
2B	INTER, DELAY	B0 = SITE 3; SITE 4; GENDER; GPA	146	0.45	1061.27
2C	INTER, DELAY	B0 = SITE 4; GENDER; GPA B1 = SITE 4	147	0.45	1058.07
2D	INTER	B0 = SITE 4; GENDER; GPA B1 = SITE 4	147	0.58	1063.83
*3	INTER, CD	B0 = SITE 4; GENDER; GPA	147	0.54	1060.00

* Final Model. Grey type indicates non-significant variables of interest.

Table 4: Overview of models

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Discussion

In this study changes over time in students' performance (within-student variation) and the influences of student characteristics (between-student variation) on performance formed two levels within the system being investigated. Variables of interest, with a focus here on the use of supplementary multimedia instruction, were modelled in a systematic process that investigated whether or not they contributed to a model that explained more of the residual variance.

Within-student Predictors

Influence of Intervention

The first stage of the study involved the investigation of changes in students' learning over time. The findings must be seen in the context of the initial Rasch analysis which highlighted those components of the swallowing process that students found easier to recall and those that were more difficult. Generally, students did not develop a deep and integrated understanding of the swallowing process (Scholten, 2000; Scholten, Keeves & Lawson, *in press*). However, it is encouraging to know that, despite the weak performance, intervention was a highly significant variable, with teaching clearly facilitating student learning without significant short term forgetting.

The second stage of the study helped to clarify those features that impacted upon the pattern of students' learning over time. The influence of IT operated at the within-student level over time (CD) and other variables focused on differences between students (SITE, GPA, AGE and GENDER).

Impact of IT

Hierarchical linear modelling confirmed the belief that use of *The Dynamic Swallow* would exert a positive influence on student learning (Scholten & Russell, 2000b). Students who use the program for longer periods of time benefit more from this supplementary study than students who spend less time in this self-directed learning. It was not expected that there would be enduring effects on learning with limited exposure of 30 minutes or less, a factor confirmed by the study.

Whereas this study was designed to determine, amongst other goals, whether or not *The Dynamic Swallow* would result in improved learning outcomes, it is not possible to do more than speculate about the reasons for such findings. However, an evaluation of Australian commonwealth-funded IT projects (Alexander, McKenzie & Geissinger, 1998) articulated some of the factors that contribute to enhanced learning, some of which apply to *The Dynamic Swallow*, as confirmed by evaluation of the program (Scholten & Russell, 2000).

One possible reason for improved learning following use of the CD-ROM relates to the likelihood of improved attitudes to learning the particular content. It had been previously determined that students enjoy using the CD (Scholten & Russell, 2000b) and there are links between motivation and high quality learning outcomes (Marton & Saljo, 1997; Prosser & Trigwell, 1998; Ramsden, 1992).

The Dynamic Swallow was designed to help students overcome particular weaknesses in core knowledge. The scoring key was sensitive to 10 underlying features and hence the demonstrated improvements in learning may reflect the value of the conceptual change strategies employed in the design of the program. The multiple representations of concepts, using text, graphics, animations, videos and voiceover, together with the interactivity associated with the program's simulations in which students could deactivate aspects of normal swallowing, appears to have resulted in improved construction and understanding of concepts, possibly related to an enhanced ability to visualise the internal system.

Increasingly, as the body of knowledge to be acquired by students expands, there is less class time available to teach particular content and appropriate material for self-directed learning would be valued by teachers. This CD was accessed individually by students outside of class time that may

have increased time-on-task, enhancing understanding of lecture content. It is likely that the delivery format of learning materials resulted in relatively increased productivity of learning through the use of animations and video. The software design makes it easy for students to navigate throughout the learning resources, readily replaying or slowing videos and animations, checking definitions in the glossary and so on, all of which is more efficient than would be the case with more traditional resources.

Students may also have responded to the opportunities for autonomy around their own learning, learning in their own time, at their own pace and in an environment of their choosing. They were free to make mistakes, without embarrassment or dire consequences for patients. Because of this they may have felt liberated to try out ideas that might otherwise have gone untested, resulting in miscomprehension.

Finally, the inclusion of high quality graphic images, including diagnostic radiography used in clinical practice, in order to highlight the links between features of interest (disordered swallowing) to those that would otherwise have appeared dry and uninteresting, may have improved perceptions related to the relevance of the normal swallow, with resultant increased motivation.

The disparate CD-ROM uptake of between 4 and 67 per cent at various sites is of concern considering the demonstrated positive effect of this form of supplementary instruction. Some teachers are better at assimilating IT than others and it is possible that this resource may need to be integrated into courses more effectively in order for its true potential to be realised. In view of the poor uptake at some sites and in recognition of the fact that teachers may not be familiar with the potential of the program, a teacher's guide has been added to *The Dynamic Swallow*. The guide includes ideas for integrating the program within the entire learning experience in the topic, including normal swallowing, disorders and treatment and incorporating assessment tasks and classroom activities. Students need support when experiencing new activities (Alexander, McKenzie & Geissinger, 1998) and preparatory activities have recently been designed to help teachers introduce the program to students. This support and guidance is especially necessary for the students who have poor computer literacy skills.

A robust statistical effect has demonstrated that *The Dynamic Swallow* enhances student learning, with increased duration of use resulting in improved learning outcomes, and with no saturation effect demonstrated. The reasons for this promotion of learning must be unpacked in a future study designed to look specifically at this program.

Influence of Between-student Variables: Site, Aptitude & Gender

Reasons for the improved performance of students from SITE 4 can also only be speculative. Future research aimed at revealing the contributing factors to better performance may provide the key to improving learning of this important content area, with possible implications for learning more broadly.

The effect of prior aptitude (GPA) is not surprising. However, high ability students' knowledge did not grow at a greater rate than did others, suggesting that with increased resources, including time on task, weaker students could also achieve similar results.

A surprising finding of the present study is the significant relative advantage for this material experienced by male students. There were no outliers to account for this phenomenon and these men were not in the group of highest ranked students. This male benefit might relate to the nature of the knowledge content. The small male advantage in spatial performance has been well-studied because of the implications for mathematics and science education (Berk, 1991). It could be argued that appreciating the normal swallow demands the ability to develop an internal visual model of the entire process, which is highly integrated and involves continually changing spatial, pressure and flow relationships, features that commonly arise in the traditionally male domain of mechanical engineering. The very low numbers of males in this study demands that these findings are interpreted with caution.

In summary, this authentic study has clarified that intervention and use of the CD-ROM, *The Dynamic Swallow*, significantly influence student learning about normal swallowing. Students' aptitude and gender significantly influence students' starting scores, as does being at SITE 4. Finally, there is an interaction between SITE 4 and intervention that is noted in some of the final models, with students at SITE 4 learning more than their peers. There are immediate implications for dysphagia instruction but further research is required in order to determine the reasons for improved performance for students using the CD and those at SITE 4.

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